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THE SUBCONSCIOUS EFFECT DURING AUDIO MONITORING

Jon Clark Bergner

Naval Postgraduate School
Monterey, California

September 1972

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THESIS

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by

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Thesis Advisor: G. K. Poock

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13. ABSTRACT

The purpose of this study was to determine if a subconscious detection effect exists in audio monitoring. The vigilance task consisted of the detection of an audio signal masked by thermal noise. Thirty signals over a sixty minute watch were presented to eighteen military officers who were divided into three equally numbered groups. The control group monitored the tape and this was their primary task. The other two groups were engaged in other primary tasks and were asked to monitor the tape as a secondary task. A statistical examination of the results indicated, at a low probability level of $p < .25$, an effect was present causing the groups engaged in monitoring as a secondary task to detect a greater percentage of the signals than the control group. The analysis also indicated that there was a significant decline in performance over time.

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The Subconscious Effect
During Audio Monitoring

by

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I. INTRODUCTION

The term, vigilance, has been defined in many different ways. One of the better definitions was stated by Mackworth [1957] when he defined vigilance as the state of readiness to detect and respond to certain specified small changes occurring at random time intervals in the environment. Vigilance did not become an area of major interest to the military until the beginning of World War II. As man's technology increased, his ability to design and construct air, surface and subsurface attack vehicles created a need for developing equipment and procedures to detect these threats in amply time to take the necessary action. Three major types of equipment were developed; radar, sonar and electromagnetic countermeasures. Due to the nature of the equipment, all of these systems require a human monitor. Man has been able to design and build computers to perform many different functions, but he has been unable to design a system to replace the human brain. The development of signal processing equipment to aid in the detection of targets has been complicated by the large number of parameters that must be evaluated and the fact that most targets are masked by some type of noise. Until a system can be developed to differentiate between the target and the noise background, man must serve as the primary monitor.

Many people feel that to increase the performance of the sensors that are now operational, new equipment must be

designed. This is a valid point, but these same people overlook the fact that the man-machine interface common to the operational systems has not been fully investigated. Improving the monitor's ability to detect a target using the present systems is another approach to increased performance. The purpose of this paper is to investigate one small area of the audio detection problem associated with the existing sonar equipment.

II. BACKGROUND

Since World War II, extensive research has been conducted in the investigation of the performance decrement associated with prolonged vigilance tasks. Due to the large volume of papers written to cover the subject and the fact that many of the papers are classified, the reader is referred to the bibliography and in particular Davies and Tune [1969] which gives a very complete listing of the experiments to date. In the following brief summary, the author has attempted to isolate the major points covered in the experiments.

The vast majority of the experiments have been concerned with identifying the physical and mental parameters which cause the decrement in visual vigilance tasks. Most of the experiments have been completed using flashing lights, deflecting meters and changing light intensity [Mackworth, 1950; and others]. It was not until the 1950's that the researchers began using the cathode-ray tube to better simulate the actual display medium. At the same time, the experiments began to center more on the actual target detection problem and not so much on vigilance testing in general. Areas of study included PPI size, shape, intensity and duration [Baker, 1963; Rittger, 1963; and others].

As the USSR and other world powers increased their submarine forces, the sonar detection problem became an area of primary interest to the United States Navy. The initial

research in the area of sonar detection was a carry over from the radar detection experiments. The majority of the experiments again were concerned with visual detections even though the audio presentation played an important role in the overall problem. This was due to the large volume of information readily available and the fact that it is easier to train a man to monitor a visual display instead of the audio receiver.

When the results of the vigilance experiments are compared, certain concepts have proven consistent. The most prevalent result encountered is that vigilance decreases with time on watch. This degardation of performance usually occurs within the first ten to thirty minutes of the watch. At the completion of the decline, the subject's performance tends to stabilize giving the standard shaped performance curve in Figure 1 [Mackie, 1964; Mackworth, 1950; and others].

Once it was established that vigilance declines as a function of time on watch, investigators began work on isolating the causes and sought to explain the decline with specific theories. Two theories which have received the greatest interest have been the Filter Theory proposed by Broadbent [1958] and the Arousal Theory set fourth by Hebb [1955]. The Filter Theory states that the nervous system contains certain filters which select and pass information to the perceptual system. These filters have a constant bias toward information channels which have not been used

recently. During the first few minutes of the watch when the monitor is concentrating on the display, the information is passed to the perceptual system. After a few minutes, the filter will be biased toward the other information channels which are not being used. If a stimulus is received, the filter will send the new stimulus to the perceptual system for processing in place of the display information. As the watch progresses, the filter is continually searching for new stimulus and the amount of display information passed to the perceptual system is decreased. This loss of display information is, by Broadbent's Theory, the cause of the performance degradation.

The Arousal Theory states that the perceptual system is triggered by irrelevant environmental stimulation. This implies that the more non-specific stimulation that the perceptual system receives, the better the performance. Hebb concluded that in the case of the vigilance task, the monotony removes the stimulation and causes the performance decline.

The motivation and attitude of the monitor also play an important role in the detection problem. If the monitor feels he is doing an important job, his performance will be better. It has been shown that increased performance can be achieved through monetary incentives [Yufer, 1962]. The area of selecting personnel to perform vigilance tasks has not received much interest. Little has been done to determine which personality traits are important to the detection problem.

The effect of specific parameters has been demonstrated in many of the experiments. While not all investigators agree, the majority have concluded that the performance decrement can be reduced by increasing the signal frequency [Bowen and Woodhead, 1956; and others], increasing the signal duration [Hamilton, 1956; Machworth, 1963; and others], increasing signal intensity [Terchner, 1962; and others] and introducing artifical signals [Baker, 1960; and others]. Many experiments have investigated the use of drugs to increase detection performance. Amphetamines have been shown to maintain performance but they have no effect on the initial detection level [Mackworth, 1950]. Although drugs do provide a solution, their use must be closely supervised in order to insure no physical damage will result from their use. The most useful result obtained to date is that many frequent rests are better than longer less frequent ones. This result can be implemented when more than one trained monitor is available.

III. OBJECTIVE

This experiment is based more on the experiences of the author and not to any great extent on the literature published to date. The phenomenon this experiment is designed to investigate is the observation that when a person is engaged in a task, he is able to unconscously percieve changes in his environment without actually knowing what change took place. An example of this is a person who works around a large number of different types of machinery. If one particular machine stops operating, the person gets the "feeling" something is different but he is not certain as to the actual change. This occurs even though the apparent overall sound intensity and tone have not changed. It has also been observed that a man performing a task, not related to the sonar detection problem, in an environment where he is subjected to the sonar returns, can make initial sonar detections before the sonar operator. This experiment is designed to investigate this phenomenon.

Many investigators have used similar experiment utilizing relevant secondary tasks in an effort to support either the Filter Theory or the Arousal Theory. By constructing an irrelevant task and treating the detection problem as secondary, the author has tried to accomplish two objectives. The first is to discover if this phenomenon can be observed under laboratory conditions and second to measure the effect it has on the detection problem.

IV. METHOD

A. EXPERIMENTAL DESIGN

The vigilance task consisted of the detection of a pulsed signal of constant frequency (800 Hz) and pulse duration (.03 s) masked by thermal noise filtered 250 cycles either side of the known frequency. The constant frequency, pulse duration and bandwidth were selected to simulate as closely as possible the signal processing equipment installed on-board United States Naval Operating Forces. The signals presented to the subjects consisted of three different signal-to-noise ratios; low, medium and high. The signal-to-noise ratios were determined during a pilot study where many different signal-to-noise ratios were presented to alerted subjects not included in the main experiment. The three levels were selected such that the probability of detecting a low signal-to-noise ratio was approximately 0.1, the probability of detecting a medium signal-to-noise ratio was approximately 0.5, and the probability of detecting a high signal-to noise ratio was approximately 0.9. During the pilot study, no consideration was given to determining false alarm probabilities.

Thirty signals were distributed over the sixty minute watch such that during each ten minute period, five signals were presented randomly to the subjects. Each ten minute period had the same composition of signal types; one low-signal-to-noise ratio, three medium signal-to-noise ratio

and one high signal-to-noise ratio. The order of presentation in each ten minute period was different and random. The randomization of the location and the order of the signals within each ten minute period was accomplished using a table of random numbers. The signals were restricted in location such that two noise pulses containing signals were always separated by at least four noise pulses without signals. The random draw accomplished this without altering the position of any signals.

The sixty minute tape was divided into 720 cycles of five second duration. During each cycle, a two second noise pulse with or without signal was presented followed by three seconds of silence. It was considered a detection if, during a cycle when a signal was present, a response was received either during the remaining noise pulse or the three seconds of silence which followed. Any other response was considered a false alarm. Each ten minute period was broken down into 120 cycles so that the noise pulses containing signals could be placed accurately. One signal of specified signal-to-noise ratio was randomly placed in each two second noise pulse selected by the random draw.

Eighteen subjects were tested for sixty minutes. The subjects were randomly assigned to three equally numbered groups. Group A was instructed to monitor the stream of noise pulses and report any detection. This was group A's only task. Group B was told that the first part of the experiment was designed to condition them to the noise

pulses and that after completing the conditioning phase they would take a second test. During the first phase, group B was allowed to read current magazines of general interest and instructed that they would still be required to report any detections. Group C was instructed in the same manner as group B. They were told their task would be to assemble a geometric puzzle and that the amount they completed would be a factor in the experiment. The subjects were not told the exact purpose of this study but they were told that conditioning during a vigilance task was being tested.

The subjects listened to the master tape through earphones which had variable volume control. They were allowed to adjust the volume setting to a comfortable level. This adjustment did not effect the signal-to-noise ratios presented to them. The subjects were allowed to eat, drink or smoke during the test. The experiment was conducted in the Human Engineering and Man-Machine System Design Laboratory at the United States Naval Postgraduate School located in Monterey, California. An accurate record of each subject's responses was maintained to determine whether a detection was made, a signal was missed, or a false alarm was committed.

The independent variables used in this test were time on watch and whether the subjects were involved in a secondary task. The dependent variables were the percentage of signals detected and the number of false alarms. This experiment can be described as a two-factor experiment, type of task

and time on watch. To analyze the data, the experiment was divided into six ten minute periods.

B. SUBJECTS

Eighteen military officer students and faculty members at the United States Naval Postgraduate School served as subjects for this experiment. The ages of the subjects ranged from 25 to 38 years of age. A small proportion of the subjects had served as Anti-Submarine Warfare Officers but due to the nature of this experiment the fact was not considered significant. Each subject was tested once and none of the subjects had participated in the pilot study to set the signal-to-noise ratios.

C. APPARATUS

The system used to present the master tape to the subjects consisted of an Ampex PR-10 magnetic tape recorder and stereo earphones with separate volume controls. A silent button-type response switch was used by the subjects to report detection of a signal.

The schematic represented in Figure 2 shows the basic set up of equipment used to produce the master test tape. An oscilloscope was used to monitor the original taping and subsequent transfer taping to insure that no portion of the signal was lost or modified.

D. PROCEDURE

Prior to the arrival of each subject, the magnetic tape recorder was turned on and permitted to warm up. The

magnetic tape recorder, earphones and response switches were then checked to insure that they were in proper working order. All settings were examined to verify that consistent experimental conditions were being maintained.

When the subject entered the laboratory, he was asked to remove his watch and take a seat at the desk located in a sound proof chamber. The subject was then instructed to carefully read the following instruction:

> This experiment is designed to test your ability to detect a signal masked by noise. This task is designed to be similar to the detection problem faced by sonar operators. During the testing period, you will hear noise pulses for two seconds followed by three seconds of silence. During a small number of the noise pulses, a signal will be present. This signal will occur randomly within the two second period. Some of the signals will be very easy to detect while others will be very difficult. Your job during this experiment is to detect the signal.
>
> Prior to the start of the experiment, sample pulses of noise with and without signals will be presented to you. During this experiment, you will wear earphones which are adjustable in volume. You may adjust the volume to any setting which is comfortable. This adjustment will not effect the signal-to-noise ratio presented to you. Before the

sample tape, a constant stream of noise will be presented so that you can adjust the volume.

You are to indicate the presence of a signal by pressing the response button located on the desk. This should be done as soon after the signal is detected as possible. You may respond either during the remaining noise pulse or during the silence that follows.

During the experiment you may eat, drink or smoke. This is to recreate the actual conditions of a sonar watch. The experiment will last approximately one hour.

As a sample of the experiment, you will hear sixteen cycles (two seconds of noise and three seconds of silence equal one cycle) as a test run. Again, some of the signals will be easier to detect than others. Do not be disturbed if you can not locate all of the signals on the test run. This is a function of your auditory threshold and will be taken into account. This test tape is not representative of the actual experiment because during the experiment, the signals will be less frequent and randomly spaced. Once the experiment begins, it will continue until completion and no portion of the tape will be replayed.

PRACTICE RUN

1	5*	9*	13*
2	6	10	14
3*	7*	11*	15*
4	8	12	16

(*indicates a signal present)

QUESTION ?

If the subject was a member of groups B or C he was also given one of the following:

GROUP B

For the first part of the experiment, you will be conditioned to the noise background. During this portion, you will be allowed to read any of the reading material on the desk. You will still be required to respond if a signal is detected. After this conditioning, the reading material will be removed and another much shorter test will be taken.

GROUP C

For the first part of the experiment, you will be conditioned to the noise background. During this poriton, you will be required to complete the puzzle on the desk. You will still be required to respond if a singal is detected. After this conditioning, you will take a much shorter test. You will notice that part of the puzzle has been completed and an outline provided. Please work from the parts provided so that the degree of completion can be measured.

After reading the instructions, each subject was permitted to ask questions to insure that he completely understood what was expected of him during this experiment. After each subject was instructed, he was allowed to listen to noise so that he could adjust the earphones to a comfortable level. The subject was then given sixteen sample noise pulses, seven of which contained signals. After the practice run was completed, the subject was again allowed to ask questions. At this point, the subject was allowed to remove the earphones and relax for two minutes. The subject was then told to replace the earphones and adjust them to a comfortable position. The sixty minute vigilance task was then begun.

After the testing was completed, the subject was informed of his performance and asked not to discuss the experiment with other students until all testing had been completed.

V. RESULTS

The tabulated results of the experiment are located in Tables I and III. Figure 3 shows the mean percentage of signals detected and indicates that there appears to be a performance decrement as a function of time on watch. It also appears to show that the decline in performance did not begin to stabilize until after approximately fifty minutes of the watch. Figure 3 also indicates that the rates of decline in performance were similar and the only differences was in the percentage level of signals detected by each group. Group A averaged 49.0%, group B averaged 51.6% and group C averaged 59.5% signals detected when considering all signals presented.

Due to the fact that the data was in the form of a ratio and had a range from zero to one, an arcsine transformation was performed on the detection percentages as recommended by Winer [1962] in an attempt to stabilize the variances. Table II shows the results obtained from a nested-factorial analysis of variance performed on the transformed data points, with the subjects nested into groups but common to the six time periods.

The results in Table II show that the difference between the signals detected by each group was statistically significant but only at the probability level of $p < .25$. The analysis also showed that there was a significant decline in performance over time. The interaction between the groups and the time period was not significant.

An analysis of variance was not performed on the number of false alarms. This was due to the fact that false alarms tend to be a function of the person taking the test and not a measure of the condition under consideration. This can be seen by examing the percentage of false alarms contributed by each individual. In this experiment, 65% of the false alarms were committed by 27% of the subjects. Table III shows the number of false alarms made by each subject and Figure 4 presents the data in graphic form. The only conclusion that can be drawn is that the mean number of false alarms appears to decrease as a function of time on watch. An extension of the median test [Dixon and Massey, 1957] utilizing the chi-square statistic was completed, but the number of expected false alarms in each cell of the contingency table was too small to derive any conclusions.

VI. DISCUSSION

The results of the analysis of variance showed that the difference between the three groups, in terms of the percentage of detections, was statistically significant but at a very low probability level. This determination does not prove that a person engaged in a primary task and treating the detection problem as secondary, can detect a larger percentage of the signals presented. This does however suggest that the effect could exist.

The greatest problem encountered in this experiment is insuring that the subject is actually treating the detection problem as secondary. If the subject treats the detection as primary, then the secondary task will become an irrelevant stimulus. If this were the case, the performance decrement could be explained, depending on the reader's preference, by the Filter Theory or the Arousal Theory.

The analysis of variance also showed that the decrement over time was statistically significant. This is consistent with the findings of the majority of the investigators who have tested vigilance tasks. It is interesting to note that the decline in performance did not begin to stabilize as early as expected. Most investigators have found that the performance tends to stabilize between ten and thirty minutes after the task had begun. The stabilization in this experiment did not begin until approximately fifty minutes into the watch. This represents only a guess due to th

fact that the experiment ended at sixty minutes and there was no way of knowing for certain the direction in which the percentages were moving.

When considering the performance of each group in Figure 3, it is apparent that the groups involved in secondary tasks had a slightly higher percentage of detections than the control group that was just monitoring the audio display. The fact that the group involved in working the puzzle had a higher percentage of detections than the group that was reading indicates that the type of primary task might have an effect on the performance.

It is recommended that in future investigations of the subconscious effect, that the length of the watch be increased to at least two hours and the number of subjects also be increased so that a larger data base can be obtained. It is also recommended that the use of three different signal-to-noise ratios be discontinued and one signal-to-noise ratio which gives approximately a .5 probability of detection be used. In the analysis, it was discovered that only one out of the 108 high signal-to-noise ratios presented was missed and that six detections out of the 108 low signal-to-noise ratios presented were made. This fact tends to support the findings by other investigators that the higher the signal intensity, the better the performance. An interesting determination was made when checking which singals were detected or missed. All of the low signals which were detected were located immediate

after the presentation of a high signal. It was also noted that the majority of the medium signals detected were also located after the presentation of a high signal. This indicates that the high signal might have acted as an alerting device. All of the above recommendations require a great deal more investigation to find out the actual part they play in the vigilance decrement problem.

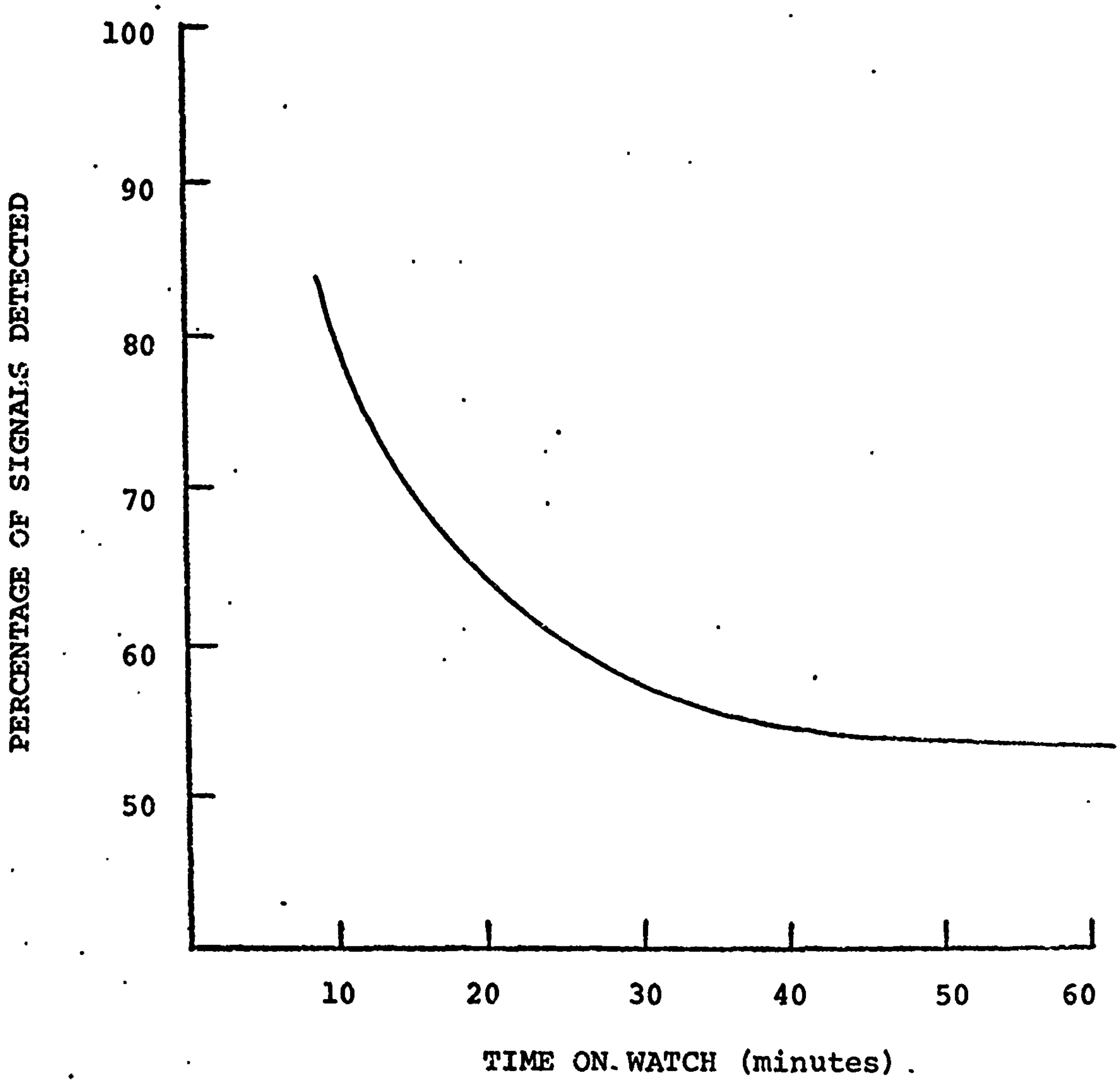

FIGURE 1. EXAMPLE OF A STANDARD PERFORMANCE CURVE. PERCENTAGE OF SIGNALS DETECTED AS A FUNCTION OF TIME ON WATCH

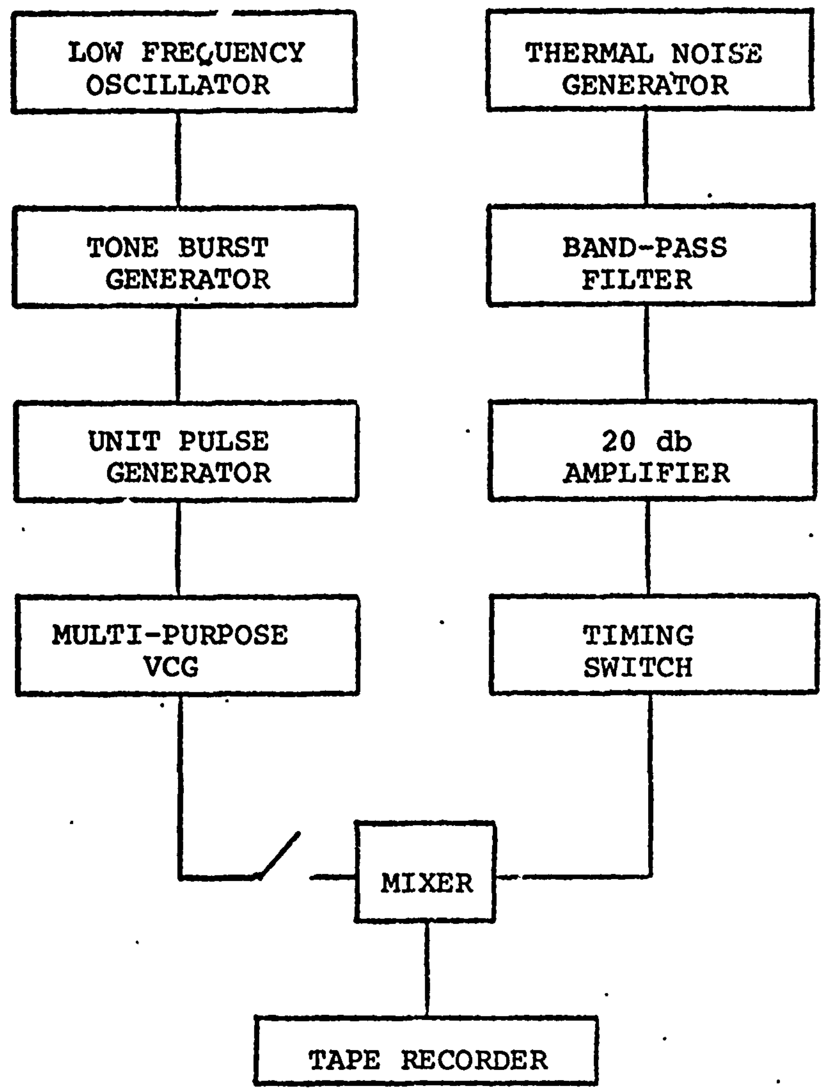

FIGURE 2. BLOCK DIAGRAM OF THE RECORDING SYSTEM

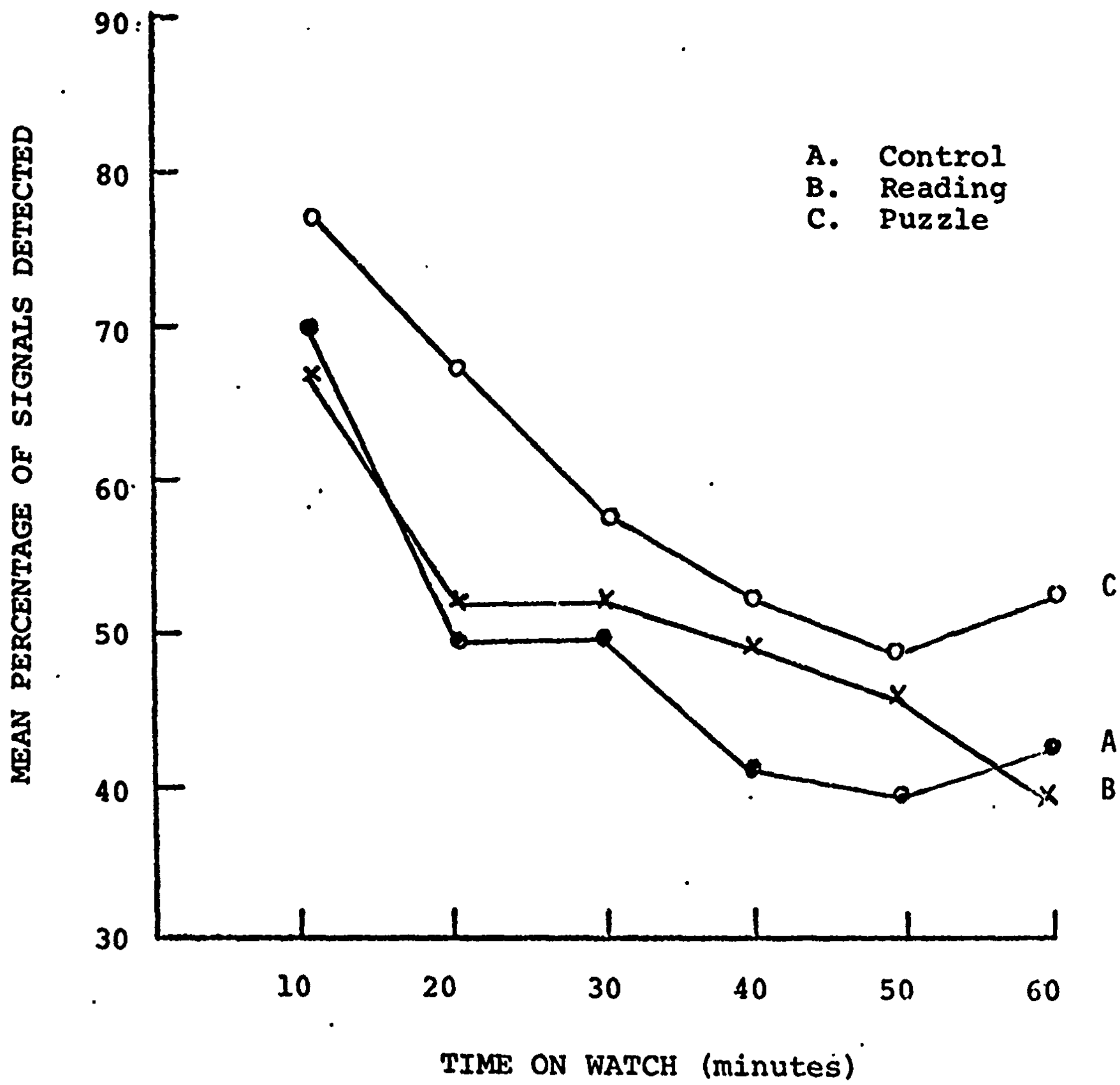

FIGURE 3. MEAN PERCENTAGE OF SIGNALS DETECTED AS A FUNCTION OF TIME ON WATCH

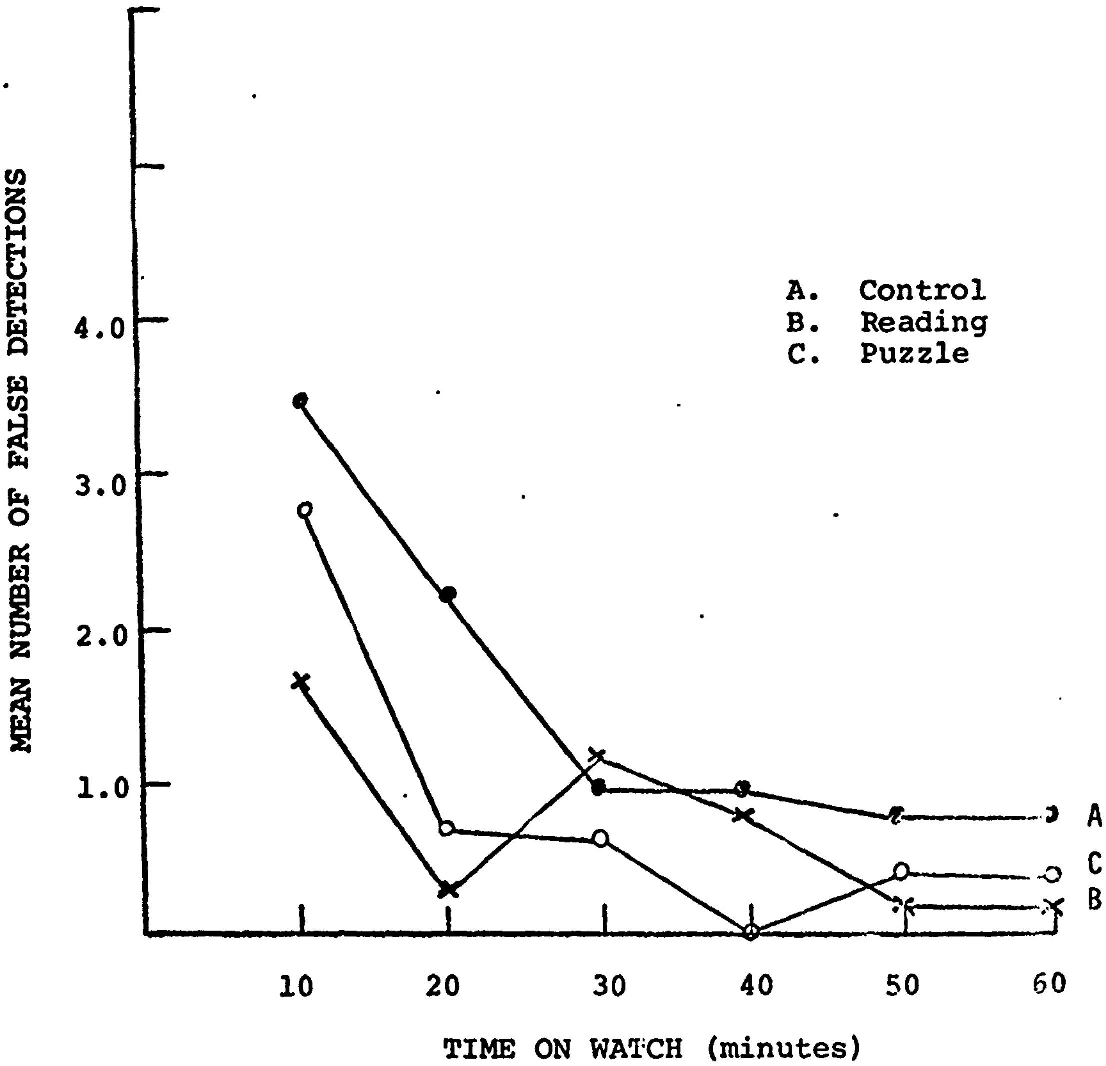

FIGURE 4. MEAN NUMBER OF FALSE DETECTIONS AS A FUNCTION OF TIME ON WATCH

TABLE I

PERCENTAGES OF SIGNALS DETECTED

GROUP	SUBJECT	10 minute blocks I	II	III	IV	V	VI
A	1.	.6	.2	.4	.4	.2	.6
	2.	.4	.4	.4	.2	.2	.2
	3.	1.0	.6	.6	.8	.6	.4
	4.	1.0	.8	.6	.6	.6	.6
	5.	.8	.6	.8	.4	.4	.6
	6.	.4	.4	.2	.2	.4	.2
	average	.70	.50	.50	.43	.40	.43
B	7.	.6	.6	.8	.4	.6	.4
	8.	.4	.6	.4	.8	.6	.4
	9.	.8	.8	.6	.4	.6	.6
	10.	1.0	.4	.6	.4	.4	.4
	11.	.6	.6	.4	.4	.2	.4
	12.	.6	.2	.4	.6	.4	.2
	average	.67	.53	.53	.50	.47	.43
C	13.	.8	.8	.6	.6	.6	.6
	14.	.8	.6	.6	.4	.6	.6
	15.	.6	.6	.4	.2	.4	.4
	16.	.4	.6	.6	.6	.6	.6
	17.	1.0	.6	.4	.4	.4	.4
	18.	1.0	.8	.8	1.0	.4	.6
	average	.77	.67	.57	.53	.50	.53

TABLE II

ANALYSIS OF VARIANCE OF THE ARCSINE TRANSFORMATION OF SIGNALS DETECTED

SOURCE	df	ms	F	p(less than)
Between Subjects	17			
Group (G)	2	1.1259	1.1134	.25
Error (between)	15	1.0112		
Within Subjects	90			
Time Periods (T)	5	1.5227	6.9848	.001
G x T	10	0.0577	0.2646	N.S.
Error (within)	75	0.2180		
Total	107			

TABLE III

NUMBER OF COMMISSIVE ERRORS

GROUP	SUBJECT	I	II	III	IV	V	VI
		10 minute blocks					
A	1.	3	2	1	1	0	0
	2.	0	0	0	0	0	0
	3.	9	5	4	2	2	4
	4.	7	4	0	2	1	0
	5.	3	1	1	1	0	0
	6.	0	2	0	0	2	1
	average	3.50	2.33	1.00	1.00	0.83	0.83
B	7.	6	0	2	1	0	0
	8.	0	0	1	0	0	0
	9.	2	0	0	1	0	0
	10.	0	0	0	2	0	1
	11.	1	0	2	0	0	0
	12.	1	1	2	1	1	0
	average	1.66	0.16	1.16	0.83	0.16	0.16
C	13.	5	3	0	0	1	0
	14.	7	0	1	0	0	0
	15.	0	0	0	0	0	0
	16.	0	1	0	0	0	1
	17.	0	0	3	0	0	0
	18.	5	0	0	0	1	0
	average	2.83	0.66	0.66	0.0	0.33	0.33

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